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FRIEDEL'S LAW OF RATIONAL SYMMETRIC INTERCEPTS[1]

WITH BIBLIOGRAPHY OF IRRATIONAL THREE-FOLD AXIS OF SYMMETRY

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There are two generally accepted fundamental laws of geometrical crystallography: (1) the law of constancy of interfacial angles proved for quartz by Steno in 1669, but first established as a general law by Rome de l'Isle in 1772 after the invention of the contact goniometer; (2) the law of simple rational indices, which may also be expressed as the law of zones, discovered by Haüy in 1784. As has been pointed out by Friedel,[2] Bravais' law of maximum reticulate density is a more precise form of Haüy's law of simple rational indices.

The so-called law of symmetry proposed by Haüy in 1815, which may be expressed thus: "Similar parts of a crystal are similarly modified"[3] does not deserve the name of a law. It is a statement of no particular significance, for symmetry is determined by similar modifications.

There is, however, a third law of geometrical crystallography, viz., the law of rational symmetric intercepts[4] (or parameters), which was formulated by G. Friedel in 1905. Apparently this contribution of Friedel has been overlooked or ignored. As far as can be learned the writer (28) is the only one besides Friedel himself who has referred to the law of rational symmetric intercepts in print. The object of this note is to call attention to Friedel's work in order that it may receive the attention that it deserves.

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[1] Paper presented at the annual meeting of the Mineralogical Society of America, Washington, D. C., Dec. 29, 1923.

[2] *Bull. Soc. Franc. Min.*, **30**, 326-455 (1907).

[3] Miers, Mineralogy, p. 15, London, **1902**.

[4] Friedel uses the term parameter instead of intercept, but on account of the ambiguity in the use of parameter the writer has substituted intercept for it.

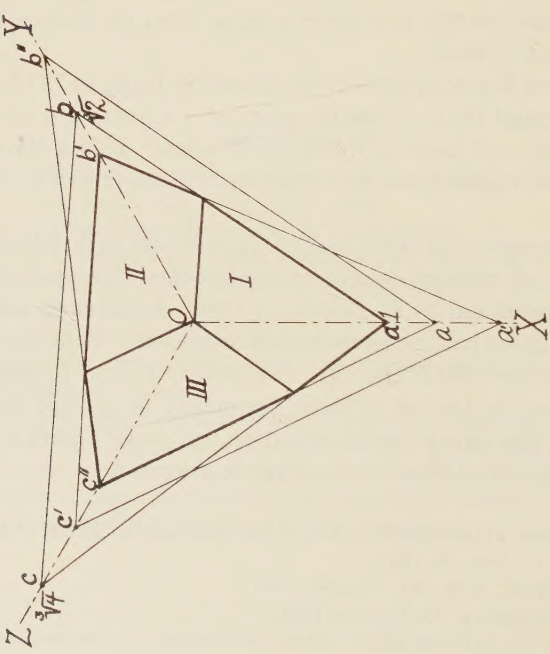

Fig. 1

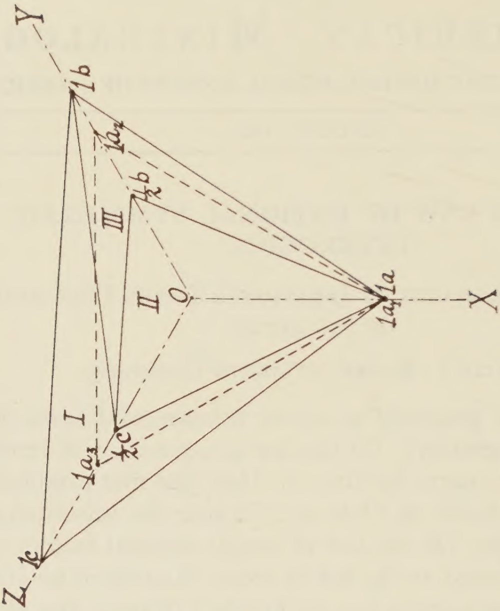

Fig. 2

Diagrams to illustrate irrational three-fold axis of symmetry and Friedel's law of rational symmetric intercepts.

As was first pointed out by Gadolin (1) in a classic paper read in 1867 and published in 1871, an axis of ternary or threefold symmetry in a crystalloid polyhedron is not necessarily a zone-axis and is not necessarily normal to a possible face or plane.[5] In other words a polyhedron may have planes with simple rational indices and irrational symmetric intercepts (or parameters). This is shown graphically in Figs. 1 and 2. Since the time of Gadolin the "irrational ternary axis" has been the subject of much discussion by crystallographers. Prominent among those who have taken part in the discussion are Fedorov (3, 5, 7, 9, 12, 13), Hecht (4, 6, 8, 14), Souza-Brandão (10, 18), Viola (11, 15, 17), and Friedel (23, 25). The irrational three-fold axis of symmetry is mentioned in the treatises or text-books of Lewis (19), Hilton (21), Sommerfeldt (24), Bouasse (26) and Friedel (27), but is entirely ignored by most authors. While perhaps it may appropriately be omitted from elementary text-books, it should certainly find a place in the more advanced text-books and treatises.

It is not my purpose to enter into a detailed discussion of the controversy relative to the possibility of the irrational three-fold symmetry axis. A bibliography of the subject is appended to this article for those who wish to look into the matter at length. The essential features of the question may be presented very simply by means of diagrams. The lack of suitable drawings to illustrate the subject under discussion probably accounts for a general lack of understanding of the principles involved.

In Fig. 1 *OX*, *OY*, and *OZ* represent in orthographic projection three axes of reference equally inclined to each other at either right or oblique angles. A line normal to the plane of the drawing through the origin, *O*, represents a three-fold axis of symmetry. The plane I with the intercepts *a*, *b*, and *c* on counter-clockwise rotation of 120° will give rise to the plane II with the intercepts a', b' and c'; and this plane on a further rotation of 120° will give rise to the plane III with intercepts a'', b'' and c''. These three planes meet to form a trigonal pyramid as indicated in the drawing. Now if the intercepts of the plane I are chosen so as to be in the ratio of $a : b : c = 1 : \sqrt[3]{2} : \sqrt[3]{4}$,[6] the intercepts of the plane II are $a' : b' : c' = \sqrt[3]{4} : 1 : \sqrt[3]{2}$, and the intercepts of the plane III, $a'' : b'' : c'' = \sqrt[3]{2} : \sqrt[3]{4} : 1$. Here the intercepts on three symmetric axes of reference are irrational. We may take one of the planes as a standard or unit face and express the other planes in terms of our standard as is customary in crystallography. Let us select plane I as our (111) face. We may shift the planes II and III parallel to themselves so that they cut the OX-axis at the point a. Then all three planes intersect the OX-axis at a common point. The result of such shifting is indicated in Fig. 2. The new intercepts of plane II are $a : b : c = \frac{\sqrt[3]{4}}{\sqrt[3]{4}} : \frac{1}{\sqrt[3]{4}} : \frac{\sqrt[3]{2}}{\sqrt[3]{4}}$ which is obtained by dividing each intercept by $\sqrt[3]{4}$. Similarly, the new intercepts of plane III are $a : b : c = \frac{\sqrt[3]{2}}{\sqrt[3]{2}} : \frac{\sqrt[3]{4}}{\sqrt[3]{2}} : \frac{1}{\sqrt[3]{2}}$, obtained by dividing each intercept by $\sqrt[3]{2}$.

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[5] The exceptional character of a three-fold axis of symmetry has been brought out by Lewis (19- p. 114). The proof that an axis of symmetry of even degree is a possible zone-axis and is normal to a possible face depends upon the fact that two similar (homologous) zone-axes are coplanar with the axis, and in the case of an axis of odd degree, $n > 3$, the proof depends upon the fact that two dissimilar (non-homologous) edges are coplanar with the axis. "Here the homologous zone-axes form the edges of a trigonal pyramid, and no pair of them lies in a plane containing the triad axis. Nor can an auxiliary pyramid be formed by the edges of alternate faces."

Since we selected plane I as our standard or unit face, it may be expressed by the Weiss symbol $1a : 1b : 1c$ or the Miller symbol (111). Plane II expressed in terms of the unit face is $1a : \frac{1}{2}b : \frac{1}{2}c$ or (122). Plane III expressed in terms of the unit face is $1a : 1b : \frac{1}{2}c$ or (112). The relations are shown in the following tabulation:

		Weiss	Miller
Plane I	$Oa : Ob : Oc = 1 : \sqrt[3]{2} : \sqrt[3]{4} = 1 : \sqrt[3]{2} : \sqrt[3]{4} =$	$1a : 1b : 1c =$	(111)
Plane II	$Oa' : Ob' : Oc' = \sqrt[3]{4} : 1 : \sqrt[3]{2} = \frac{\sqrt[3]{4}}{\sqrt[3]{4}} : \frac{1}{\sqrt[3]{4}} : \frac{\sqrt[3]{4}}{\sqrt[3]{4}} =$	$1a : \frac{1}{2}b : \frac{1}{2}c =$	(122)
Plane III	$Oa'' : Ob'' : Oc'' = \sqrt[3]{2} : \sqrt[3]{4} : 1 = \frac{\sqrt[3]{2}}{\sqrt[3]{2}} : \frac{\sqrt[3]{4}}{\sqrt[3]{2}} : \frac{1}{\sqrt[3]{2}} =$	$1a : 1b : \frac{1}{2}c =$	(112)

The relations indicated may be proved either mathematically or graphically as is done in the drawings. If we substitute for the values $\sqrt[3]{2}$ and $\sqrt[3]{4}$, 1.2599 and 1.5874 respectively, it is easy to prove that the above expressions are correct.

Here is actual demonstration that in a crystalloid polyhedron it is mathematically possible to have rational indices of the faces and irrational axial ratios for the symmetric axes of reference.

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[6] The intercepts in general may be $1 : \sqrt[3]{n} : \sqrt[3]{n^2}$ where n is any small integer. In order to construct a diagram it is necessary to use a particular value for n; in Figs. 1 and 2 it has the value 2.

This is possible with the four following types of symmetry according to Friedel (23, 25): A_3, trigonal pyramidal class; $\overline{AP}_6(A_3)$ (C), rhombohedral class; $4A_3.3A_2$, tetartoidal class; $4A_3(4\overline{AP}_6).3A_2.3P(C)$, diploidal class. Friedel suggested the possibility of two additional crystal systems for these four divisions. The first two constitute a "système ternaire irrational" and the other two, a "système cubique irrational." Crystals belonging to the "irrational ternary system," if such exist, would not possess either prisms, pinacoid, or pedion. The only forms possible would be trigonal pyramids, and rhombohedrons. In the "irrational cubic system" neither octahedrons, tetrahedrons, rhombic dodecahedrons, trapezohedrons, or trisoctahedrons could occur. The only forms possible would be diploids, pyritohedrons, tetartoids, and cubes.

For example in Fig. 2 the face shown by dotted lines is an impossible face with the axes of reference postulated. But it has been found that the pedion, pinacoid, and prism are found on crystals with the symmetry A_3 and $\overline{AP}_6(A_3)(C)$ and also that the tetrahedron or octahedron, rhombic dodecahedron, trapezohedron, and trisoctahedron are common on crystals belonging to the tetartoidal and diploidal classes.

In other words in all crystals with either a single axis of three-fold symmetry or four axes of three-fold symmetry the parameters or intercepts of a unit face on three axes of reference symmetrical to a three-fold axis are equal or rational. In Fig. 2 for example, the three axes of reference $a_1 : a_2 : a_3$ are equal and interchangeable. This is a fact of observation and Friedel (23) cleared up the whole matter by formulating the following law of rational symmetric parameters: "Two symmetric edges of a crystal have the same parameter." It is only fair to state that this law was hinted at by Viola (17) in 1897 and by Lewis (19) in 1899, but Friedel deserves the main credit for its recognition. His paper entitled "Sur les bases expérimentales de l'hypothèse reticulaire" will become, I believe, one of the classics of geometrical crystallography.

This empirical law of observation practically proved the existence of the space lattice in 1905, seven years before direct proof of the space lattice was furnished by the work of Laue and his associates in 1912.

This important contribution of Friedel's, brilliant in its simplicity, has been overlooked by nearly all crystallographers. The object of this note is to call attention to its importance in the development of the theory of crystal structure.

As I conceive it, there are three stages in the history of the science of crystal structure (leptonology of Rinne). (1) The mathematical stage beginning with the work of Bravais in 1849 and culminating in that of Fedorov, Schoenflies, and Barlow (1890-1894). (2) The crystallographical stage in which Friedel (1905) takes the most prominent part. And (3) the experimental stage beginning with the work of Friedrich and Knipping on sphalerite in 1912 and continuing up to the present.

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ZIRCON, A CONTACT METAMORPHIC MINERAL IN THE PEND OREILLE DISTRICT, IDAHO[1]

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INTRODUCTION

The purpose of this paper is to call attention to a rather widespread transfer of zirconium from some intrusive ocks into invaded sedimentary rocks in the Pend Oreille mining district, Idaho. This district, an area 15 by 20 miles, was recently studied by a party of the U. S. Geological Survey under Dr. Edward Sampson. The contact metamorphism was investigated in detail, and in the course of this work the prevalence of very minute zircon crystals in the most metamorphosed rocks turned the attention of the writer to a special study of this problem. Conclusions were reached only after a study of over a hundred thin sections and the examination of the heavy residues of more than thirty rock samples. In addition, Professor R. A. Daly of Harvard University very kindly loaned a number of thin sections of similar rocks from the Canadian boundary which were entirely unaffected by igneous metamorphism, and served as an interesting comparison with the rocks from the locality in northern Idaho.

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[1] Published by permission of the Director of the U. S. Geological Survey.

The rocks affected by contact metamorphism contain very numerous microscopic zircon crystals which are shown to be of other than detrital origin. As the bulk of the rocks containing the mineral is great, the aggregate transfer of material was very considerable. Descriptions of typical occurrences of zircon in these rocks, are followed by a review of the literature on zircon in contact metamorphic zones, in some of which the zircon is definitely shown to be of pneumatolytic origin.

OCCURRENCE IN THE PEND OREILLE DISTRICT

The sedimentary rocks of the district belong to the Belt series (Algonkian) and the Cambrian. Except for one calcareous member, the Belt rocks consist of a great thickness of thoroughly indurated sandstones and shales, and the Cambrian rocks consist of quartzite, shale and limestone. A very large batholith extends from the west side of the district westward for many miles, and three stocks, each from two to three miles across, outcrop within the area. These igneous bodies are so large and are so near to each other even at the surface that a widespread effect of igneous metamorphism would be expected in the invaded sedimentary rocks. In fact, no locality in the quadrangle was found where the sedimentary rocks did not show at least some microscopic evidence of igneous metamorphism.

Detrital zircon is commonly present in the non-calcareous rocks; but little or none is present in the calcareous rocks. For this reason the occurrences of zircon in the metamorphosed facies of these two classes of rocks is considered separately.

IN NON-CALCAREOUS ROCKS

To distinguish metamorphic from detrital zircon in the non-calcareous rocks it was necessary to establish the following criteria:

1. SIZE. The detrital zircon grains are of a size more or less in proportion to the size of the accompanying quartz grains. They are seldom less than .02 mm in diameter. A very few tiny grains less than .01 mm in diameter were noted as inclusions in detrital quartz grains.

The metamorphic zircon grains are commonly not as large as .02 mm and in many rocks very minute grains about .005 mm in diameter are very abundant. In many specimens examined both detrital and metamorphic grains are present indicating that the latter are not formed by recrystallization of the former.

2. RELATIVE ABUNDANCE. As the detrital grains are relatively large they are easily collected by separation in heavy solutions. The quantity of detrital zircon grains separated in this way does not exceed a maximum of about 0.2 per cent by weight of the whole sample, either in the rocks of the Pend Oreille district or in those from near the Canadian boundary. This percentage is equivalent to 20 to 25 grains in the average thin section.

The metamorphic zircon grains are usually so minute that it is impossible to separate them by heavy liquids. The comparison of relative abundance, except in one or two instances, is, therefore, made on the number present in the thin sections. For example, two or three hundred of the tiny grains occur in each thin section of the metamorphosed quartzite found at the mouth of Falls Creek on the east side of Pend Oreille lake, a large body of water extending nearly the whole length of the area. The grains are so numerous that frequently twenty-five are visible in the field of the microscope with moderate magnification at one time. Similarly metamorphosed quartzite on the north slope of South Chilco mountain where the rock was invaded by a quartz monzonite exhibits a like abundance of the minute grains of zircon.

Further proof of the addition of zirconium is afforded by the zirconia determinations in two pairs of analyses of siliceous sediments made by Mr. J. G. Fairchild in the laboratory of the U. S. Geological Survey. The first pair are of specimens of quartzite of the Blacktail[2] formation on the north side of Chilco Mountain and the second pair are of an argillite of the Prichard formation in Kilroy Bay. According to these the quartzite of the Blacktail formation at the igneous contact contains 0.05 per cent ZrO_2 whereas the same rock 250 yards from the contact contains only 0.03 per cent. The argillite of the Prichard formation at the igneous contact contains 0.07 per cent ZrO_2 whereas the rock one half mile from the contact contains only 0.03 per cent. Mr. Fairchild stated that his accuracy on the zirconium analysis was approximately .005 per cent.

[2] A new formation name in the Pend Oreille district. The Blacktail is equivalent to the St. Regis and Revett formation of the Coeur d'Alene district, as will be set forth in the report of the U. S. G. S. on the Pend Oreille district now in preparation by Edward Sampson and J. L. Gillson.

3. Luster. The luster of the zircon grains as suggested by Trueman[3] aided in determining the origin of the zircon in some rocks. The detrital zircon is usually lusterless while the metamorphic crystals are very brilliant.

4. Position in Enlarged Quartz Grains. The position of the tiny zircon grains in those beds of the metamorphosed Blacktail quartzite that show pronounced quartz enlargements was an important criteria. If the tiny zircon crystals were confined to the portions of the quartz grains inside of the original rim they might be considered as inclusions in detrital quartz. If they were confined to the interstitial areas between the rims of the original rounded quartz grains, they might be considered as detrital zircon grains deposited contemporaneous with and interstitially between the quartz grains. A number of instances were noted where the grains lie across or in the original rim of a quartz grain and the zircon grains are as common inside of the old rims as in the interstitial areas. This distribution favors the view of a metasomatic origin of the zircon grains.

5. Association with a Pneumatolytic Mineral, Tourmaline. Metamorphic zircon is commonly associated with tourmaline Although detrital tourmaline was recognized in some of the thin sections of rocks from near the Canadian Boundary, the tourmaline in the sedimentary rocks in the Pend Oreille district occurs as subhedral crystals which very sharply crosscut the detrital grains and must be of metasomatic origin. Wherever a considerable quantity of tourmaline was found, the tiny zircons were invariably present, whereas in moderately metamorphosed rocks in which tourmaline was absent the few zircon grains present are all relatively large, and were probably of detrital origin.

In Calcareous Rocks

The calcareous formations were found to contain zircon only when metamorphosed. Six samples of the nearly unmetamorphosed calcareous rocks of the Wallace formation from different parts of the district were ground, and the powder treated with heavy liquids. Not a single grain of zircon was collected in the heavy residues. In the Cambrian limestone no zircon was found in pure carbonate beds, and only one or two grains of doubtful zircon was recovered from a shaly bed at Port Rock.

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[3] Trueman, J. D., The origin of foliated crystalline rocks: *J. Geology*, **20**, 255-6, (1912).

The Wallace formation is not everywhere calcareous. In selecting samples of the metamorphosed rocks of the formation for examination, specimens were selected which contained such minerals as were known to form in the particular district only by the metamorphism of calcareous rocks. The Wallace formation on the west side of Bernard Peak contains an amphibole never found in the metamorphosed non-calcareous sediments of the Pend Oreille district. In the thin sections of this rock very minute grains of very high index and strong birefringence, principally zircon and titanite, are abundant,and those of zircon are readily distinguished with the highest magnification. A few grains are as large as .01 mm, but grains as small as .005 mm are very common. Identical observations were made on calcareous Wallace rocks from the west shore of Pend Oreille lake below the three conspicuous hills known as the "Three Sisters." In three thin sections the minute zircon crystals are very numerous, at least three hundred being present in each section.

In the Cambrian limestone the abundance of metamorphic zircon is as striking. In a rock from the lake shore south of the mouth of South Gold Creek the zircon grains are large enough to concentrate with heavy liquids. A two gram sample was ground and immersed in a liquid of sufficient density to float the diopside and scapolite. Subhedral crystals of zircon formed 20 per cent of the heavy concentrate, or 0.5 per cent of the rock.

In each of several thin sections of very strongly metamorphosed limestone beds from Vulcan Hill, east of Lakeview, there are more than 100 grains approximately .005 mm in diameter.

This evidence from the calcareous rocks, more striking than that in the non-calcareous rocks, leaves no room for doubt that zircon is a contact-metamorphic mineral. The sequence of the mineralization under the contact metamorphic conditions in the sedimentary rocks of the Pend Oreille district indicates that the zircon belongs to a second[4] or pneumatolytic stage in the metamorphism and formed contemporaneously with tourmaline, biotite, andalusite, cordierite, vesuvanite, garnet, diopside, apatite, etc. Unlike these minerals the zircon is of unrestricted occurrence and is found in both the calcareous and non-calcareous rocks.

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[4] A manuscript describing the contact metamorphism in the Pend Oreille area has been prepared, and will appear as a chapter in the bulletin to be published by the U. S. Geological Survey.

OTHER OCCURRENCES OF ZIRCON IN CONTACT METAMORPHIC ZONES

Although zircon is not commonly referred to as a metamorphic mineral, the following review will show that this mode of occurrence is widespread.

In the nearby Coeur d'Alene district, Idaho, zircon is also very abundant in the sedimentary rocks which are almost directly correlated with the pre-Cambrian formations of the Pend Oreille district. Calkins[5] suspected that some of the zircon might be of contact origin, although he thought that the mineral was probably for the most part clastic.[6]

Zircon has been found as a contact mineral by a number of observers. Thürach[7] held the opinion that zircon could form from watery solutions and cited the example of zircon crystals in druses in the chlorite schist of Tyrol. In the crystalline limestone of Grenville, Ont., Hoffman[8] found large crystals of zircon with well developed faces, probably formed by contact metamorphism. Trueman[9] believed in the contact origin of zircon, citing the enlarged grains of zircon in a quartzite cut by granite at Rib Hill, Wausau, Wisconsin. Trueman,[10] however, stated that he did not know of a case where microscopic zircons developed in small grains throughout a contact rock.

Clarke[11] in describing the synthesis carried out by Deveille considers as possible the pneumatolytic origin of zircon and says further[12] that zircon occurs, though not commonly, in contact limestones.

Watson and Hess[13] state that zircon forms occasionally as a product of contact metamorphism and they list several places where it was probably formed by pneumatolytic agencies and give as further evidence for an origin by igneous emanations the common association of zircon with magnetite ores.

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The zirkite deposits of Brazil contain zircon, and although not well understood, are described by Meyer[14] as probably of pneumatolytic origin.

Zircon has been found as a contact mineral by other observers. Dana[15] states that it occurs in crystalline rocks, especially granular limestones. One of the localities given is the southern base of Mount Eve, near Warwick, N. Y. Beck[16] stated that at this place the zircon was associated with scapolite in the limestone. Kemp and Hollick,[17] who studied the intrusive granite of Mount Eve, did not find any zircon in place, and were not certain whether the scapolite replaced igneous rock or limestone. The crystals described by Beck, however, are very unlike usual magmatic zircon crystals and may, therefore, be tentatively regarded as products of contact metamorphism.

Goldschmidt[18] found zircon as a contact mineral in certain rocks in the Christiana basin. He states that in the endomorphosed contact zones of eruptive rocks the number of zircon crystals was increased. The zircon crystals ranged up to 5 mm in length. In other rocks of the endomorphic zone tiny crystals of zircon were found in druses. In the hornfels of the exomorphic zone the zircon occurs in biotite and the grains are made conspicuous by pleochroic halos. He is not sure, however, that these zircons in the sedimentary rocks are of contact origin.

Tilley,[19] in describing the metamorphism of the Comrie area in England states that in the hornfelses, zircon has a uniform distribution, and is the more readily recognized when it is enclosed in biotite or cordierite, so as to give the characteristic pleochroic halos. He does not, however, discuss its pneumatolytic origin and it may be simply of residual detrital origin.

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[14] Meyer, H. C., Brazilian zirkite deposits: Monthly prices for November, Foote Mineral Co., pp. 29-31, 1916. Quoted by Schaller, Waldemar, Zirconium and rare earth minerals. *U. S. Geol. Survey, Mineral Resources,* **1916,** Part II, pp. 378-9, **1919.**

[15] Dana, E. S., The system of mineralogy, 6th Ed., p. 485, (**1914**.).

[16] Beck, L. C., Mineralogy of New York, p. 380, (**1843**).

[17] Kemp, J. F. and Hollick, Arthur, The granite at Mounts Adam and Eve, Warwick, Orange County, New York, and its contact phenomena: *Annals New York Acad. Sci.,* **VII,** pp. 638-654, (1893).

[18] Goldschmidt, V. M., Die Kontaktmetamorphose im Kristianiagebiet: *Videnskapsselskapets Skrifter, I, Mat. naturv. Klasse,* No. 11, pp. 280-1, (**1911**).

[19] Tilley, C. E., Contact metamorphism in the Comrie area: *Quart. Jour. Geol. Soc. London,* **80,** p. 57, (1924).

Zircon occurs in the phlogopite deposits at Renfrew, Ontario, which De Schmidt[20] thinks are contact metamorphosed limestones. Eckermann,[21] gives zircon as a contact mineral, stating that it occurs in the limestone in the neighborhood of the igneous contact, and that it was derived by pneumatolytic transport of material from the igneous source. In the limestone surrounding the essexite of Mount Royal, at Montreal, Dolan[22] found zircon to be one of the minerals resulting from the effects of pneumatolytic contact metamorphism.

These descriptions prove that zircon is known in many contact zones, in some if not all of which it has been formed under pneumatolytic or hydrothermal conditions.

The author wishes to thank Professor E. S. Larsen of Harvard University who examined a number of the thin sections and carefully went over the manuscript before publication.

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[20] De Schmidt, H. S., Mica, its occurrence, exploitation and uses: *Canada Dept. Mines, Mines Branch*, No. **118,** p. 277 (1912).

[21] Eckermann, Harry von, The rocks and contact minerals of the Mansjö Mountain: *Geol. Fören. Förh.*, p. 343, (**1922**).

[22] Dolan, E. P., The contact metamorphic zone of Mount Royal, Montreal, P. Q.: *Trans. Royal Soc. Canada*, 3rd ser. vol. **17,** section IV, p. 131, (1923).

JAMESONITE FROM SLATE CREEK, CUSTER COUNTY, IDAHO[1]

Earl V. Shannon, *U. S. National Museum*

There has long been a tendency among geologists and, to a less extent, among mineralogists to refer to the mineral jamesonite all of the so-called "needle-ore" or "feather-ore" minerals of fibrous structure which are found by qualitative tests to be lead sulphantimonites. The name jamesonite has thus had a sort of "natural history" significance which it has in no wise earned. This has been pointed out in several papers by L. J. Spencer.[2] Investigations by the present writer[3] have indicated that boulangerite is far more widespread than is generally supposed, and that many of the fibrous sulphantimonites, formerly referred to jamesonite, are in reality boulangerite. Spencer has pointed out that jamesonite is distinguished from the other minerals of this group by the fact that it has a fairly good cleavage across the prismatic direction which causes free fibers or acicular crystals to break across the elongation upon slight bending.

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[1] Published by permission of the Secretary of the Smithsonian Institution.

The purpose of the present short paper is to describe a specimen of a granular-massive sulphosalt from Idaho which upon analysis has been found to be genuine jamesonite, a comparatively rare mineral.

The specimen in question was received for identification from Mr. Stewart Campbell, Idaho State Inspector of Mines. The locality is given as "On the head of Slate Creek near the summit of Railroad Ridge. Slate Creek is a tributary of Salmon River flowing north and into the river about 12 miles west of Clayton in Custer County."

The mass as received weighed about 12 ounces (260 grams) and, with the exception of minor amounts of quartz, pyrite, siderite and arsenopyrite, consisted entirely of the sulphosalt. Mr. Campbell, influenced by the writer's discussions of the occurrence of boulangerite in Idaho, was inclined to identify it as the latter minera but it differs in appearance, particularly in being blacker gray in color and more brilliant in luster with a tendency to tarnish iridescent instead of dull.

Mr. M. N. Short of the U. S. Geological Survey very kindly submitted a portion of the specimen to a careful mineragraphic examination and reports it homogeneous except for the nonmetallic gangue (quartz and siderite) and a few per cent of pyrite and arsenopyrite. The material examined by Mr. Short was found to be optically strongly anisotropic and gave the following reactions when tested with the standard microchemical reagents as reccommended by Davy and Farnham: with HNO_3 quickly stains black; HCl fumes tarnish iridescent–not washed off; KCN feeble or negative; $FeCl_3$ negative; KOH quickly tarnishes dark brown; $HgCl_2$ negative. The reaction with KOH immediately distinguishes this mineral, in polished surfaces, from boulangerite which gives a negative reaction with this reagent.

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[2] L. J. Spencer: Plagionite, heteromorphite and semseyite as members of a natural group of minerals, *Mineralog. Mag.*, **12**, 55-68 (1899). Note on "featherore": identity of domingite (="warrenite") with jamesonite, *Mineralog. Mag.*, **14**, 207-211 (1904).

[3] Earl V. Shannon: Boulangerite, naumannite, bismutoplagionite and a silver-bearing variety of jamesonite, *U. S. Nat. Museum Proc.*, **58**, 589-607 (1920).

Although the specimen as a whole was found to contain several per cent of arsenopyrite and pyrite, these occurred interstitially with relation to the jamesonite grains and it was possible, by careful selection of the coarsely crushed particles, to avoid them to a large extent. Moreover, they remained largely undissolved when the analyzed sample was brought into solution by gentle warming in concentrated hydrochloric acid. Consequently the following analysis represents a comparatively pure sample of the sulphosalt. The results and ratios of the analysis are as follows:

ANALYSIS AND RATIOS OF JAMESONITE FROM IDAHO

Constituents	Per cent		Ratios	
Insol.	1.24			
Pb	40.32	.195	.049x4	1.02x4
Fe	3.68	.066	.066x1	1.37x1
Sb	32.92	.274	.049x6	1.02x6
S	21.40	.667	.047x14	.98x14
	99.56			

The ratios of the above analysis yield the formula $Pb_4FeSb_6S_{14}$ or $4PbS.FeS.3Sb_2S_3$, which is Schaller's formula for jamesonite, the only serious deviation from whole numbers being in the iron. This is doubtless to be explained by partial solution of the pyrite or arsenopyrite present as admixed impurity, or by the presence of a minor amount of siderite in the sample.

The structure of the specimen is coarse massive-granular and does not approximate the "needle-ore" or "feather-ore" nature ordinarily considered typical of jamesonite. Grains which are individual crystals reach dimensions of 5 by 10 millimeters or more and show well defined cleavages in several directions. The cleavages are of sufficient interest to merit careful description. Spencer, in the papers cited above, has classified the acicular lead sulphosalts as having brittle and flexible needles. Jamesonite he places in the former class since it has a basal cleavage across the prismatic direction, along which the needles break upon slight bending. Spencer's emphasis upon the basal cleavage as a diagnostic character for this mineral is correct. Textbooks give the cleavages for this mineral as "basal, perfect; *b*, *m*, less so."[4] Spencer comments upon this as follows[5]: "The statement of the cleavages of jamesonite given in the textbooks dates back to F. Mohs (1824). The basal cleavage *c*(001), though good, can scarcely be described as perfect, and the others, *m*(110) and *b*(010), probably do not exist. The latter were not to be observed on any of the jamesonites I have examined; any apparent cleavage in these directions can be explained by the parallel aggregation of the acicular crystals." Spencer's specimens consisted of acicular crystals not exceeding ½ by 5 mm in dimensions and it is not surprising that needles of such size could not be split to demonstrate imperfect cleavages in the vertical direction. The specimen from Idaho, containing crystals up to 5 by 10 mm, shows well defined cleavages in the prism zone, equally as good as the basal cleavage which, as Spencer states, is good though not perfect. A number of cleavage fragments were mounted on the goniometer and found to have cleavages in four directions, one the basal cleavage emphasized by Spencer and three in the vertical zone. Two of these are parallel to the faces of a prism, the average angle of which is 62°51′, and the third evidently a pinacoid truncating this prismatic angle. Comparison of these angles with Spencer's crystallographic angles in the paper last cited shows that the prism cannot be the unit prism for which the angle $m(110) : m'''(1\bar{1}0)$ is 78°38′. They do agree, however, with the prism $n(120)$ for which the angle $n(120) : n'(\bar{1}20)$ is 62°44′. This makes the pinacoidal cleavage *b*(010) so that this jamesonite, at least, shows good, though not perfect, cleavages parallel to *n*(120), *b*(010), and *c*(001).

When the two are side by side, the jamesonite is seen to have a much blacker gray color than boulangerite, a more brilliant luster and a tendency to tarnish iridescent instead of dull. It is interesting to record this occurrence of the really rare mineral jamesonite, especially since, to judge from the size and quality of the specimen received, the mine is capable of furnishing excellent material for distribution in collections.

[4] Edward S. Dana: System of Mineralogy, 6th edition, page 122, **1892**.

[5] L. J. Spencer: Analysis of crystallized jamesonite, *Mineralog. Mag.*, **14,** 310 (1906).

TETRADYMITE FROM THE HAILEY QUADRANGLE, IDAHO[1]

Earl V. Shannon, *U. S. National Museum*

A number of specimens collected by Mr. Stewart Campbell, Idaho State Inspector of Mines, and forwarded by him to Mr. C. P. Ross of the U. S. Geological Survey, for identification, were submitted to the writer for examination. Since a preliminary blowpipe examination failed to determine the identity of the mineral it has been analyzed in the Museum's laboratory and found to be the bismuth sulfo-telluride, tetradymite. Since this is the first record of the occurrence of this rare mineral in the State, which is substantiated by definite analytical data made upon material of demonstrated purity, the following brief description is presented. The writer desires to express his thanks to Messrs. Campbell and Ross for the privilege of examining and describing the mineral and to Mr. M. N. Short, also of the U. S. Geological Survey, for making a careful mineragraphic examination of polished surfaces which showed the mineral to be unusually pure.

The locality is not given more definitely than "near the head of Trail Creek." This places the occurrence in the Hailey Quadrangle and in either Blaine or Custer Counties as the upper reaches of this Creek cross the county line.

The mineral consists of aggregates of bluish-gray grains in a gangue of quartz and carbonate, calcite and dolomite, which appears to form narrow veinlets cutting the limestone. Polished surfaces show the tetradymite to be arranged in somewhat dendritic aggregates of small grains in the gangue.

A sample separated with methylene iodide contained a considerable proportion of mixed grains and hence included some gangue. This included no other metallic mineral, however, than the tetradymite as shown by Mr. Short's metallographic studies. This was analyzed with the following results:

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ANALYSIS AND RATIOS OF TETRADYMITE

	Original	Recalculated	Ratios		
Quartz	1.90				
$CaCO_3$	3.04				
$MgCO_3$	1.63				
Pb	1.37	1.48	.007	.278	.97x2
Bi	51.98	56.35	.271		
Se	2.00	2.17	.027	.306	1.06x2
Te	32.86	35.62	.279		
S	4.04	4.38	.137	.137	.95x1
	98.82	100.00			

The ratios indicate with satisfactory exactness the formula Bi_2Te_2S or $2Bi_2Te_3 \cdot Bi_2S_3$. The agreement would doubtless be still closer were it not for the selenium which may replace both tellurium and sulfur, being of intermediate atomic volume, although these elements may not replace each other.

The qualitative reactions of the mineral are very obscure and did not lead to its recognition. With sulfuric acid it gives only a faint and fugitive red color which does not suggest abundant tellurium. In the closed tube a faint upper ring of whitish oxide is obtained, succeeded downward by a ring of sulfur tinged reddish by selenium. With long heating a lower black ring of tellurium is obtained but this is faint. The mineral fuses to globules. Heated in the flame it volatilizes coloring the flame bluish-green with the production of white fumes which give odors of sulfur dioxide mixed with a faint odor of selenium which suggests arsenic.

BOOK REVIEWS

DIE MINERALIEN DER NIEDERRHEINISCHEN VULKANGEBIETE, MIT BESONDERER BERÜCKSICHTIGUNG IHRER BILDUNG UND UMBILDUNG. Reinhard Brauns. E. Schweizerbart'sche Verlagsbuchhandlung, *Stuttgart*, 1922. Quarto, 225 pages, 3 portraits, 32 figures, 40 plates, each with 4 photomicrographs in photogravure.

This excellent treatise deals with the geological history as revealed by the microscopical characters of the minerals of the lower Rhenish volcanic province. The specimens examined were selections from the collections at the University of Bonn, which contain 4210 specimens of the Laacher See region, 1100 from Eifel, 3120 from the Siebengebirge and 1870 from Finkenberg. Several thousand thin sections were studied of which 160 are reproduced in photogravure. About 300 minerals are described with reference to their physical and optical properties, occurrence, formation and alteration products. Many new chemical analyses are likewise given.

This work is undoubtedly one of the best examples of regional mineralogy and petrography that has appeared in recent years. W. F. H.

GESTEINS—UND MINERALPROVINZEN. Band 1: Einführung. Paul Niggli and P. J. Beger. Chemismus der Eruptivgesteine insbesondere der Lamprophyre. Gebrüder Borntraeger, *Berlin*, 1923. 602+XVI pages, 202 figures.

While this work is of especial interest to petrographers, a brief note calling attention to its appearance seems desirable even in a mineralogical journal.

This volume, which is the first of a series, compares mineral and rock associations of different regions in order to determine, if possible, the fundamental underlying chemical and physical laws. The book may be divided into six parts. The first five were written by Niggli and discuss petrographic provinces, magmatic differentiation, and the mineral and chemical composition of the chief types of magmas. In Chapter IV Niggli introduces his new system for the calculation of rock magmas, while in Chapter V magmas are classified and discussed under three main types, lime-alkaline series, soda series and potash series.

Part six, contributed by Beger, is devoted to the chemistry of the lamprophyres. This section comprises 360 pages, more than half of the book, and deals exclusively with the basic dike rocks. 382 chemical analyses are recalculated and recorded and the conclusion reached that this study seems to confirm Bowen's theory of differentiation.

This book is another very important contribution in the field of petrography and should be on every reference shelf for frequent consultation. W. F. H.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, June 11, 1925

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with an attendance of thirty-three. In the absence of the president and vice-president the secretary, Mr. Blank, presided.

An amendment to the by-laws, creating offices of recording secretary and corresponding secretary, was laid on the table after considerable discussion. Mr. John Vanartsdalen addressed the Society on "*The Minerals of Finney's Quarry, Pa.*" This quarry is located in the Baltimore gneiss between Somerton and Newton, Bucks County. The quarry contains three different types of pegmatite veins, in and near which the interesting minerals are found. The specimens exhibited included chalcocite, bornite, chalcopyrite, pyrrhotite, hypersthene, barite and crystals of garnet and zircon. The quarry has not been operated for about ten years.

A large number of trips taken by various members during April and May were reported on and specimens exhibited. Among the notable finds were: graphite from Trevose, Pa., calcite and prehnite from Moore, N. J., andalusite from the Avondale quarries near Swarthmore, Pa., brown tourmaline from near Avondale, Chester Co., Pa., autunite and torbernite from Leiperville, Pa., rutile from Parkesburg, Pa., erythrite, crystallized pyrrhotite and pyrite from the French Creek Mines. Mr. Cienkowski exhibited a very fine group (about 40 kg.) of calcite crystals (7-9 cm long) which he found at Howellville, Pa., and presented to the Academy.

J. C. Boyle, *Secretary-protem.*

NEW MINERALS: NEW SPECIES

CLASS: SILICATES

Anauxite

E. Dittler and J. E. Hibsch: *Tsch. Min. Petr. Mitt.*, **36**, 85, 1923.

Chemical Properties: A hydrous silicate of alumina; $3Al_2O_3$. 10 SiO_2. $8H_2O$. Analysis: SiO_2 56.56, TiO_2 0.38, Al_2O_3 26.09, Fe_2O_3 2.69, MgO 0.11, CaO 0.40, H_2O 13.58. Total 99.87. (Mean of two closely agreeing analyses.)

Crystallographic Properties: Orthorhombic, with faces (110), (010), (001). $(1\bar{1}0)$:(110) nearly 60°.

Physical and Optical Properties: Platy grains, silvery white to bluish white. Luster pearly. $\alpha=1.54$, $\gamma=1.55$; $\alpha=c$, $\beta=b$,$\gamma=a$. 2V medium large. Plane of the optic axis parallel to (010). Acute bisectrix normal to the plates (001). H=2 1/2. Sp. Gr. 2.524.

Occurrence: As plates and aggregates in the clays of Bilin, Bohemia, a constituent of the so-called "cimolite." This cimolite is a mixture of the anauxite and an amorphous clay and results from the action of carbonated waters upon basalt.

Discussion: Anauxite is similar to kaolinite but seems to differ from it in some essential respects.

	Anauxite	Kaolinite
Cryst.	Orthorhombic	Monoclinic
Sp. Gr.	2.524	2.6–2.65
Orientation	Plane of optic axes || to (100)	Plane of optic axes || to (010)
Extinction	Parallel	Inclined
Composition	$3Al_2O_3.10SiO_2.8H_2O$	$Al_2O_3.2SiO_2.2H_2O$.

The relationships of the clay minerals are very obscure but anauxite, having been so well characterized, may be classed as a new species until further work clears up this group of minerals. W. F. Foshag.

DISCREDITED SPECIES

Barettite

A. D'Ambrosio: Sulla Barettite di Traversella (Barettite from Traversella), *Annal. del Museo Civico di Storis Nat. Genova*, **51**, 1, (1924).

A reanalysis of the material from Traversella, the original locality for barettite, gave the following composition: H_2O 13.04, SiO_2 41.55, MgO 39.99, FeO 2.09, Al_2O_3 3.28. This corresponds to normal serpentine. W. F. F.

Stasite

Alfred Schoep: Les Mineraux uraniferous (radioactifs) du Congo belge (The Uranium Minerals of the Belgian Congo). *Bull. Soc. Gecl. Belg.*, **33**, 190, (1923).

Stasite, given as a dimorphous form of dewindtite, is shown to be optically, as well as chemically, the same as the latter mineral. The name dewindtite is retained for the species. W. F. F.

Harringtonite

Adele Brauns and R. Brauns: Die Chemische Zusammensetzung von Harringtonite. (The chemical composition of harringtonite). *Centr. Min. Geol.*, p. 545, (**1924**).

New analyses of harringtonite from Larne, Antrim, Ireland, showed the mineral to be thomsonite or more properly faroelite. Analysis: SiO_2 41.34, Al_2O_3 30.44, CaO 11.35, Na_2O 5.20, H_2O 12.12. (Average of 3 analyses). W. F. F.

ABSTRACTS

CALCITE CRYSTALS FROM HOLYWELL, NORTH WALES. E. D. Mountain. *Mineralog. Mag.*, **20**, 212-216 (1924).

Crystals of two distinct habits are described. One type, pyramidal, consists essentially of the hex. bipyr. $(91\bar{7})$, with base and curved rhombohedron between $(33\bar{2})$ and $(55\bar{4})$ and modified by small faces of (110) and (100). The second habit, prismatic, consists of the prism $(2\bar{1}\bar{1})$ and a curved rhombohedron varying from $(11\bar{1})$ to $(55\bar{4})$, modified by (100) and a scalenohedron $(21\bar{2})$. W. F. H.

ALLOPALLADIUM FROM BRITISH GUIANA. L. J. Spencer. *Mineralog. Mag.*, **20**, 217-219 (1924).

Three metallic grains from the neighborhood of the Kaieteur gorge on the Potaro river were determined as the rare, hexagonal modification of palladium known as allopalladium. The material is brittle and the aqua regia solution yielded with ammonium chloride scarlet colored isotropic octahedrons of what is thought to be $(NH_4)_2PdCl_6$. Sp. gr. approx. 12. Good cleavage. W. F. H.

THE CHEMICAL COMPOSITION AND OPTICAL PROPERTIES OF A BASALTIC HORNBLENDE FROM HUNGARY. Miklos Vendl. *Mineralog. Mag.*, **20**, 237-240 (1924).

The optical properties and chem. comp. were determined on the same sample. SiO_2 40.17, TiO_2 3.78, Al_2O_3 15.09, Fe_2O_3 5.49, FeO 5.99, MnO 0.09, CaO 11.21, MgO 12.48, Na_2O 2.27, K_2O 1.55, H_2O+ 2.10, H_2O- 0.25. The comp. can be expressed in terms of an isomorphous mixture of metasilicates and aluminates. Sp. gr. 3.178 at 20°C. $\alpha=1.6698$, $\beta=1.6825$, $\gamma=1.6929$; $\gamma-\alpha=0.0231$. $c:\gamma=+8.8°$. $2V=82°45'$. Pleochroism was observed; α=pale yellow, β=dark brown, γ=dark olive green. W. F. H.

ON THE OCCURRENCE OF PETALITE AND PNEUMATOLYTIC APATITE IN THE MELDON APLITE, OKEHAMPTON, DEVONSHIRE. W. F. P. McLintock. *Mineralog. Mag.*, **20**, (103), 140-150 (1923).

Petalite has not previously been found in Britain but in the Meldon aplite it is quite common. It is pinkish to red in color and decomposes to a pink clay-like material which has been called montmorillonite by earlier writers. Under the microscope the clay-like material shows a fibrous structure with $n=1.49$ parallel to the length and slightly greater perpendicular thereto. The apatite also found in the aplite is no doubt of pneumatolytic origin and showed eight forms. W. F. H.